MONTHLY PROGRESS REPORT
MONTANA DOT "PERFORMANCE PREDICTION MODELS"
FEBRUARY 2004

To:	**Susan Sillick, MDT; Jon Watson, MDT**
Agency:	**Fugro-South, L.P. (Fugro)**
MDT Contract No.:	**HWY-30604-DT**
Contract Period:	**June 2001-May 2006**
Prepared By:	**Brian Killingsworth, PE, Principal Investigator**
Date Prepared:	**March 5, 2004**

PROJECT OVERVIEW

The overall objective of this research is to develop a design process and performance/distress prediction models that will enable the Montana Department of Transportation (MDT) to use mechanistic-empirical principles for flexible pavement design. The project involves a comprehensive performance monitoring and laboratory-testing program and spans a period of five years.

The specific tasks identified in the work plan are:

PHASE I
- Task 1. Literature Review
- Task 2. Review of MT DOT Pavement-Related Data
- Task 3. Establish the Experimental Factorials
- Task 4. Develop Work Plan for Monitoring and Testing

PHASE II
- Task 5. Presentation of Work Plan to MDT
- Task 6. Implement Work Plan – Data Collection
- Task 7. Data Analyses and Calibration of Performance Prediction Models
- Task 8. Final Report and Presentation of Results

CURRENT MONTH WORK ACTIVITIES AND COMPLETED TASKS

PHASE I

Task 1 – Literature Review

The purpose of the literature review was to summarize existing distress prediction models for load and non-load associated distresses and ride quality, for flexible pavements. The major types of distress considered were: fatigue cracking, permanent deformation, thermal cracking, and ride quality. The primary focus was on the models incorporated in the NCHRP 1-37A Design Guide, but other models were reviewed for their applicability to Montana materials, specifications, and conditions.

Completed: The "Literature Review," summarizing the pavement performance models to be considered within this project, was submitted to MDT in October 2001.

Planned: The results of the calibration and validation of the NCHRP 1-37A Design Guide distress prediction models have not been released. After these results become available, the team will update the draft memorandum and a final literature review report will be developed.

Task 2 – Review of MT DOT Pavement-Related Data

Under this task, the typical pavement related data specific to the State of Montana was investigated and documented. This included typical pavement structures, materials, soils, climatic conditions, traffic, key modes of distress, maintenance strategies, and pavement data collection procedures normally used on Montana roadways. The two major sources of information were the MDT data and the LTPP data for experimental sites within and adjacent to Montana.

Completed: A review of the available pavement-related data specific to the State of Montana was completed and included in the Task 3 "Experimental Factorial" and Task 4 "Sampling and Testing Plan" submitted to the MDT in October 2001.

Ongoing: Because the LTPP database is updated periodically to ensure the data is accurate and current, Fugro will continue to monitor the LTPP database and update any missing data on the test sections with time. An initial "Database Schema" was provided to MDT in October 2001 from the review of the LTPP database (Release11.5). The "Database Schema" was updated in June 2003 (Release 16) and will likely be updated again in May 2004.

Task 3 – Establish the Experimental Factorials

The experimental factorials were established to ensure a statistically sound calibration process based on a database that covers the typical combinations of pavement structure, subgrade soil type, and climate conditions specific for Montana.

Completed: The "Minimum Data Elements" report and the "Experimental Factorial" were completed and submitted to MDT in October 2001. The factorial consists of 93 LTPP test sections of which 40 are in the State of Montana and the remaining 53 in neighboring States and Canada. In addition, 10 non-LTPP, supplemental sites were established and included in the factorial. These sites are: Condon, Deerlodge/Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, and Hammond.

Task 4 – Develop Work Plan for Monitoring and Testing

Completed: A Work Plan was developed and provided to MDT in October 2001. The document contains the "Materials Sampling Plan," the "Initial Testing Plan" to document the baseline condition of each test site, the "Laboratory Testing Plan" to define the material properties and layer thickness at each test site, and the "Performance Monitoring Plan" to document time series data within the 60-month contract period.

Planned: The Long-Term Monitoring Pan will be revised after the initial analyses of the data are complete under Tasks 6 and 7.

Task 5 – Presentation of Work Plan to MDT
Completed: The Work Plan (PowerPoint) was presented to MDT by the project team in October 2001.

PHASE II

Task 6 – Implement Work Plan – Data Collection
The monitoring and testing part of the project includes 93 LTPP test sections in Montana or surrounding States and 10 supplemental non-LTPP sites. While the monitoring and testing of the LTPP sites is managed through the LTPP program and all data of interest to the project can be retrieved from the LTPP database, the monitoring and testing of the non-LTPP sites has been managed and coordinated by MDT and Fugro. Therefore, the two categories will be presented separately.

LTTP SITES
There are 93 LTPP sites included in the experimental factorial. Of these, 40 are located in Montana and 53 in neighboring States and Canada. Assessing the availability of testing and monitoring data for the LTPP sites is a tedious and time-consuming process. In addition, with each update of the LTPP database the process has to be repeated. To minimize the time and effort allocated to this task the research team developed a calibration and validation database where all the data extracted from the LTPP database is stored. A set of queries was written that can be used at any time in the future to extract the data needed from the LTPP database to update the information in the calibration/validation database. The database is now complete and populated with LTPP data. A code that runs all queries automatically was used to populate the database and will be provided with the database.

Ongoing: The population of the calibration/validation database with LTPP data is complete, and calibration analyses were initiated for the LTPP test sections. Along with the calibration exercise, a summary of available testing and monitoring data will be made and the areas of the database that lack sufficient data will be identified.

NON-LTPP SITES
The 10 non-LTPP sites are: Condon, Deerlodge/Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, and Hammond.

Completed: The "Field Investigation Report" was completed and submitted to MDT in August 2002. The report included a summary of the distress surveys, field sampling results (cores, borings, and other geotechnical information), FWD deflections (Round 1 only), and longitudinal profiles from each of the supplemental sites. The Round 1 deflection tests were backcalculated and summarized. In addition, the Round 2 deflection

testing was also backcalculated utilizing the same pavement structure information as the Round 1 data. Comparisons of the laboratory-derived values with FWD derived values were provided in the April and May 2003 monthly reports.

Unbound materials from the 10 sites selected in the experimental factorial were tested at the Fugro-South laboratory in Houston, Texas. Moisture-density curves at modified compactive effort (AASHTO T180) were derived for each of the 17 materials prior to testing. A repeated load resilient modulus test was performed for each material at optimum moisture content and maximum dry density (modified). The results of these tests were presented in the April and May 2003 monthly reports.

Asphalt concrete cores were retrieved from the 10 sites and tested. The tests performed were: indirect tensile (diametral) resilient modulus, indirect tensile strength, low-temperature indirect tensile strength, and low-temperature creep tests. All test results were presented in previous reports (March, April, and May 2003) with the exception of the data showing the low temperature indirect strength and strain at failure. The analysis of the low temperature indirect tensile strength tests was completed in January 2004. An abbreviated list of results was presented as Table 6.1 of the January 2004 progress report. Because the table was incomplete, Table 6.1 for this progress report includes the results for all 10 sites. These tests were performed on HMA cores earlier in the project.

Cores of cement treated/stabilized bases (CTB/CSB) were tested as well. However, due to specimen size requirements, only two of the seven treated base materials were tested for elastic modulus. Of the remaining five, four were tested for seismic modulus and one could not be tested. The results of the seismic tests were presented in the August 2003 monthly report. The modulus values obtained were highly variable with values of the coefficient of variation in most cases higher than 40 percent. In the near future, TTI will perform diametral resilient modulus on the same samples to increase our confidence in the results of the seismic testing. Density tests were performed on five of the seven treated base materials and the results were included in the August 2003 monthly report.

Two of the 10 non-LTPP sites, namely Deerlodge/Beckhill and Condon, contained "pulverized existing HMA and base materials," which were not sampled or tested. The layer moduli assigned to these layers in the calibration analyses are the ones backcalculated from FWD deflections

Planned: After the results of the calibration exercise on the 10 non-LTPP sites are reviewed, the decision will be made whether more sites are to be included in the testing/monitoring program. Materials are already available for four additional sites (Baum Road, Lothair, Vaughn, and Fort Belknap), of which Lothair and Baum Road have tentatively been selected for inclusion in the testing program.

TABLE 6.1 Low Temperature Indirect Tensile Strength Results

Site	ID	Temp (C)	Load at Failure (lbf)	Vertical Strain at Failure	Horizontal Strain at Failure
Fort Belknap	-20(P1-C4)	-20	-13,818	-0.001440	0.000815
	-20(P1-C10)	-20	-10,931	-0.001485	0.002020
	-10(P1-C8)	-10	-9,615	-0.001605	0.001370
	-10(P1-C14)	-10	-10,098	-0.001930	0.001305
	0(P1-C6)	0	-7,869	-0.003960	0.003675
	0(P1-C12)	0	-7,520	-0.006450	0.004690
Condon	-20(P83-C4)	-20	-12,112	-0.001765	0.001130
	-20(P83-C11)	-20	-15,805	-0.002025	0.001340
	-10(P83-C7)	-10	-10,528	-0.002415	0.002310
	-10(P83-C14)	-10	-12,435	-0.003440	0.002290
	0(P83-C9)	0	-7,520	-0.006145	0.004435
	0(P83-C5)	0	-7,144	-0.008755	0.007275
Beckhill	-20(I90-C4)	-20	-11,481	-0.001715	0.001025
	-20(I90-C8)	-20	-9,306	-0.001540	0.001595
	-10(I90-C3)	-10	-9,507	-0.002165	0.001740
	-10(I90-C7)	-10	-7,721	-0.001690	0.001760
	0(I90-C11)	0	-6,446	-0.008785	0.006460
	0(I90-C13)	0	-7,614	-0.006330	0.005070
Geyser	-20(P57-C5)	-20	-13,361	-0.002155	0.001335
	-20(P57-C9)	-20	-9,682	-0.002030	0.001620
	-10(P57-C4)	-10	-10,971	-0.003975	0.003235
	-10(P57-C6)	-10	-8,151	-0.003790	0.000790
	0(P57-C14)	0	-6,137	-0.009275	0.007770
	0(P57-C13)	0	-6,137	-0.009095	0.007465
Hammond	-20(P23-C8)	-20	-12,005	-0.001400	0.000730
	-20(P23-C9)	-20	-12,287	-0.001470	0.000625
	-10(P23-C4)	-10	-12,569	-0.002440	0.001300
	-10(P23-C12)	-10	-10,420	-0.001690	0.001045
	-0(P23-C10)	0	-8,460	-0.005060	0.003635
	-0(P23-C10)	0	-999	-0.000230	0.000100
Lavina	-20(NP14L-C7)	-20	10,000	0.001280	0.000735
	-20(NP14L-C3)	-20	-7,600	0.001065	0.000720
	-10(NP14L-C6)	-10	-9,360	0.001880	0.001100
	-10(NP14L-C12)	-10	-10,500	0.001925	0.001460
	0(NP14L-C9)	0	-7,000	0.004640	0.003830
	0(NP14L-C10)	0	-7,000	0.003900	0.002065

TABLE 6.1 Low Temperature Indirect Tensile Strength Results (Continued)

Site	ID	Temp (C)	Load at Failure (lbf)	Vertical Strain at Failure	Horizontal Strain at Failure
Perma	-20(S382-C4)	-20	-10,756	-0.001820	0.000910
	-20(S382-C14)	-20	-13,374	-0.001650	0.000955
	-10(S382-C5)	-10	-9,776	-0.002285	0.001655
	-10(S382-C12)	-10	-12,072	-0.002725	0.001905
	0(S382-C10)	0	-8,675	-0.007165	0.004730
	0(S382-C11)	0	-8,916	-0.005015	0.004030
Roundup	-20(NP14-C5)	-20	-11,307	-0.001310	0.000885
	-20(NP14-C12)	-20	-7,735	-0.000840	0.000455
	-10(NP14-C3)	-10	-10,273	-0.001610	0.001475
	-10(NP14-C13)	-10	-8,903	-0.001700	0.001480
	0(NP14-C7)	0	-8,138	-0.003000	0.004295
	0(NP14-C9)	0	-7,211	-0.002480	0.001900
Silver City	-20(S279-C6)	-20	-10,998	-0.001335	0.000740
	-20(S279-C11)	-20	-10,393	-0.001315	0.001155
	-10(S279-C5)	-10	-12,367	-0.002880	0.001600
	-10(S279-C9)	-10	-11,414	-0.002390	0.001485
	0(S279-C8)	0	-6,889	-0.007165	0.005645
	0(S279-C14)	0	-7,802	-0.006320	0.004415
Wolf Point	-20(P25-C5)	-20	-10,232	-0.001030	0.000880
	-20(P25-C13)	-20	-11,454	-0.001105	0.001135
	-10(P25-C4)	-10	-10,743	-0.002225	0.002960
	-10(P25-C9)	-10	-10,689	-0.001740	0.001210
	0(P25-C7)	0	-8,742	-0.005590	0.004935
	0(P25-C14)	0	-7,869	-0.009310	0.006095

Task 7 – Data Analyses and Calibration of Performance Prediction Models

The first objective of Task 7 is to demonstrate the calibration technique required to develop and maintain the various model calibration coefficients that will be used by the department both now and in the future. As discussed with Montana DOT, four major distress types were considered in the experimental plan that require prediction models and calibration coefficients. These include fatigue cracking (both surface initiated and bottom initiated surface cracks), thermal cracking, rutting or permanent deformation, and ride quality. A second objective of this task will be the calibration and validation database, which will include all the data necessary to validate and calibrate the pavement performance models considered.

Completed: The calibration technique (or the specific steps required to determine calibration coefficients) was demonstrated to MDT utilizing models similar in nature to the NCHRP 1-37A Design Guide models. The project team made a presentation to the department in August 2003,

which included a progress report, findings, and an illustration of the calibration exercise for the Silver City test section.

The calibration and validation database has been finalized and populated with LTPP data. A set of queries was used to extract the data from the LTPP IMS database to the MDT calibration and validation database. These queries are supported by the current structure of LTPP Data Release 16 (R16). Changes to the structure of the data or the tables in future data releases will require modification/reconstruction, of the current set of queries. For example, the structure of the traffic tables in the data release Version 16 differs from those in the previous versions. The queries written to extract traffic data from earlier releases had to be modified to suit the table structures in the new release. However, such modifications to the LTPP tables are few in number. It is anticipated that further changes will be made to the traffic tables in the future LTPP data releases and hence the traffic queries may need to be updated in the future.

A macro was developed to run the queries in the required sequence to populate the calibration/validation database. The macro is designed to first clear existing data related to LTPP sites from the calibration/validation database and then to populate the database with the information from the latest LTPP data release. The macro was tested and the tables were filled with the information from the latest data release (R16). The calibration/validation database was sent to MDT (CD format) in January 2004.

Ongoing: An initial calibration exercise was performed for the 10 non-LTPP experimental sites. Material test data together with historical traffic and climatic data were used to predict the performance of these sites in terms of fatigue cracking and rutting in the asphalt concrete layer and rutting in the base and subgrade layers. Predicted distress was compared to results of the two distress surveys available for these sites (June 2002 and June 2003) and to the rutting measurements taken in October 2001. The results of this exercise were included in the July-September 2003 Quarterly Report and are currently under the review by the team.

A calibration analysis, similar to the one performed on the non-LTPP, was started on the LTPP experimental sites. The availability of LTPP data will continue to be reviewed. The completeness of the data will be documented and the need for additional information will be assessed. The team is currently in the process of retrieving the data needed for analysis from the Calibration/Validation Database.

An error in the units used for penetration values was identified in the LTPP database and the calibration/validation database: the LTPP data dictionary, data collection form, and data entry form all call for PENETRATION_77_F and PENETRATION_115_F to be reported in millimeters. The QC ranges (5-120 and 10-250 respectively) imply results should be in 0.1 mm. It is obvious that 250 mm (9.84 in.) far exceeds the maximum measurement of the testing apparatus. It seems likely that values actually entered in the table are a mix of mm and 0.1 mm. A problem report has been submitted identifying the issue. At the earliest, this issue may be resolved with the next LTPP data upload, which will take place in May 2004 and the corrected data will be available only sometime in late June 2004 at the earliest.

Planned: Continue population of the calibration/validation database with information from the 10 non-LTPP sites.

Note that the calibration analyses performed so far do not specifically address the values of the calibration coefficients, but are limited to comparisons of predicted to measured distress using several widely used performance models (not necessarily the NCHRP 1-37A Design Guide models). Upon release of the NCHRP 1-37A Design Guide, the team will replace the current versions of the models with the Design Guide models and then proceed to the actual calibration of model coefficients. In addition, climatic/moisture data will be extracted from the Design Guide environmental database, which includes information for Montana and surrounding regions.

Task 8 – Final Report and Presentation of Results
No activity.

PROBLEMS / RECOMMENDED SOLUTIONS
No problems were encountered during last month and none are anticipated next month.

NEXT MONTH'S WORK PLAN
The activities planned for next month are listed below:

- Coordinate with MDT personnel on an as-needed basis.
- Finalize review of calibration exercise for non-LTPP sites and continue analysis of the LTPP sites.
- Continue populating the database with the data from non-LTPP sites.

FINANCIAL STATUS
The Financial Summary I table shows the estimated expenses incurred during the reporting period.

The Financial Summary II table provides the total project expenditures by the Montana and FHWA fiscal years in comparison to the allocated funds for each fiscal year.

The Financial Summary III-A chart illustrates total expenditures from inception of the project June 2000 through December 2003. The Financial Summary III-B chart reflects total project expenditures from January 2004 to the end of the project, May 2006.

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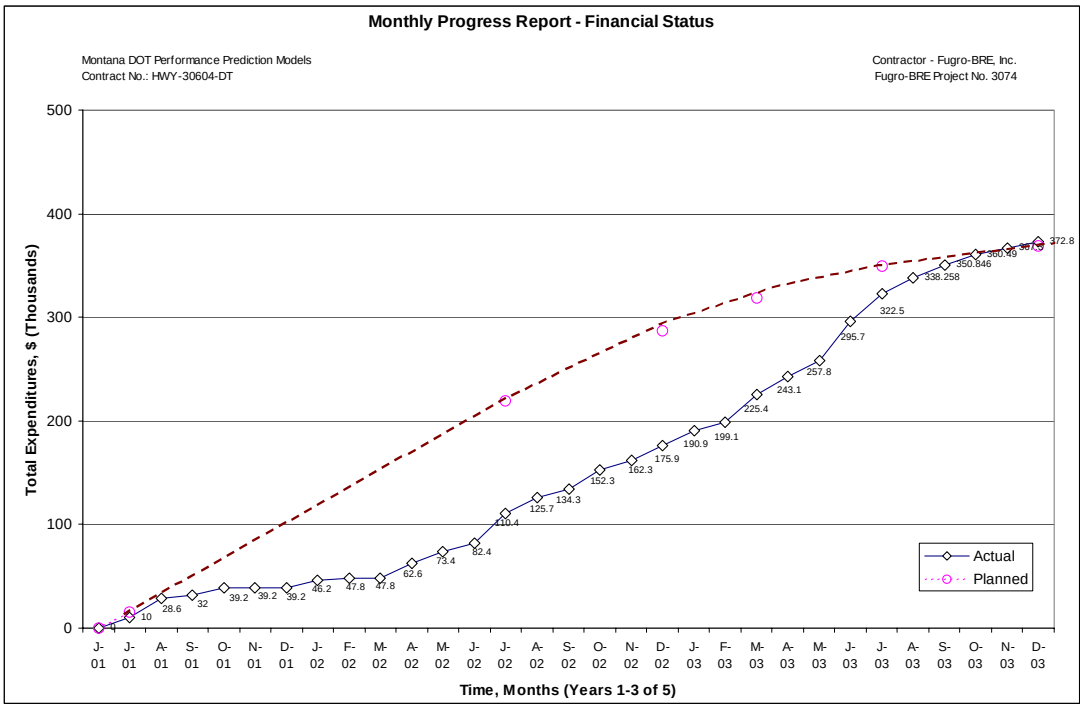
Financial Summary I
Estimated Expenses for Reporting Period: Fugro-BRE

Cost Element	Last Month's Cumulative Project Costs, $	Current Month's Expenditures, $	Cumulative Project Costs, $
Direct Labor	86,960	1,673	88,632
Overhead	124,352	2,392	126,744
Consultants/Subcontractors	4,050	0	4,050
ERES/ARA	24,044	563	24,607
Parsons-Brinckerhoff	12,093	0	12,093
SME	523	0	523
Dr. Matthew Witczak	0	0	0
Dr. Mark Hallenbeck	3,129	0	3,129
Travel	14,607	0	14,607
Testing	71,994	0	71,994
Other Direct Costs	6,273	108	6,381
Fee	34,803	474	35,276
TOTAL	382,830	5,208	388,039

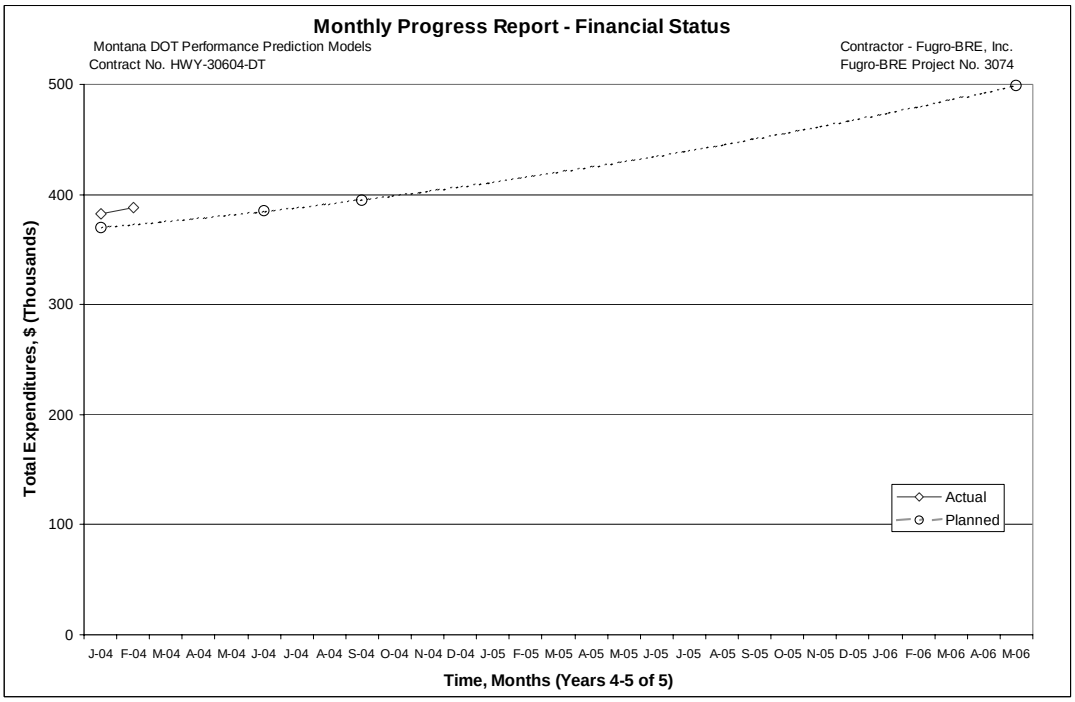
Financial Summary II
Total Expenditures by Fiscal Year: Montana and FHWA

MONTANA DOT FISCAL YEAR			**FHWA FISCAL YEAR**		
Fiscal Year	Cumulative Allocated Funds, $	Cumulative Expenditures, $	Fiscal Year	Cumulative Allocated Funds, $	Cumulative Expenditures, $
6/1/2000-6/30/**2001**	15,000	*0	6/1/2000-9/30/**2001**	65,000	31,996
7/1/2001-6/30/**2002**	218,969	82,420	10/1/2001-9/30/**2002**	258,969	102,303
7/1/2002-6/30/**2003**	348,969	213,291	10/1/2002-9/30/**2003**	358,969	216,187
7/1/2003-6/30/**2004**	388,969	92,295	10/1/2003-9/30/**2004**	398,969	253,637
7/1/2004-6/30/**2005**	428,969	---	10/1/2004-9/30/**2005**	438,969	---
7/1/2005-6/30/**2006**	498,969	---	10/1/2005-9/30/**2006**	498,969	---
TOTAL	498,969	388,036	TOTAL	498,969	388,038

*June 2001 expenditures were combined with July 2001 expenditures.



Financial Summary III-A: Total Expenditures By Month June 2000 – Dec 2003



Financial Summary III-B: Total Expenditures By Month Jan 2004 – May 2006